"The possible JLAB multipass machine experiment would appear to be potentially very significant in this regard too. Some upper management encouragement to JLAB might be useful in helping to get PAC approval." **eRHIC R&DAC, Nov. 2015**

ER@CEBAF

ERHIC R&DAC, BNL, Apr. 8, 20
On behalf of the ER@CEBAF collaboration: F. Méot

INTRODUCTION

• **A discussion with JLab started a little more than a year ago, regarding the possibility of performing multiple-pass, high energy energy-recovery R&D using CEBAF, as part of eRHIC ERL based EIC R&D**

▪ **Since the summer last year,**

(i) a collaboration group has formed :

I. Ben-Zvi, M. Bevins, A. Bogacz, D. Douglas, C. Dubbe, Y. Hao, P. Korysko, C. Liu, F. Méot, T. Michalski, M. Minty, F. Pilat, V. Ptitsyn, G. Robert-Demolaize, Y. Roblin, T. Roser, T. Satogata, M. Spata, C. Tennant, P. Thieberger, M. Tiefenback, N. Tsoupas,

(ii) a joint BNL-JLab biweekly meeting is being held

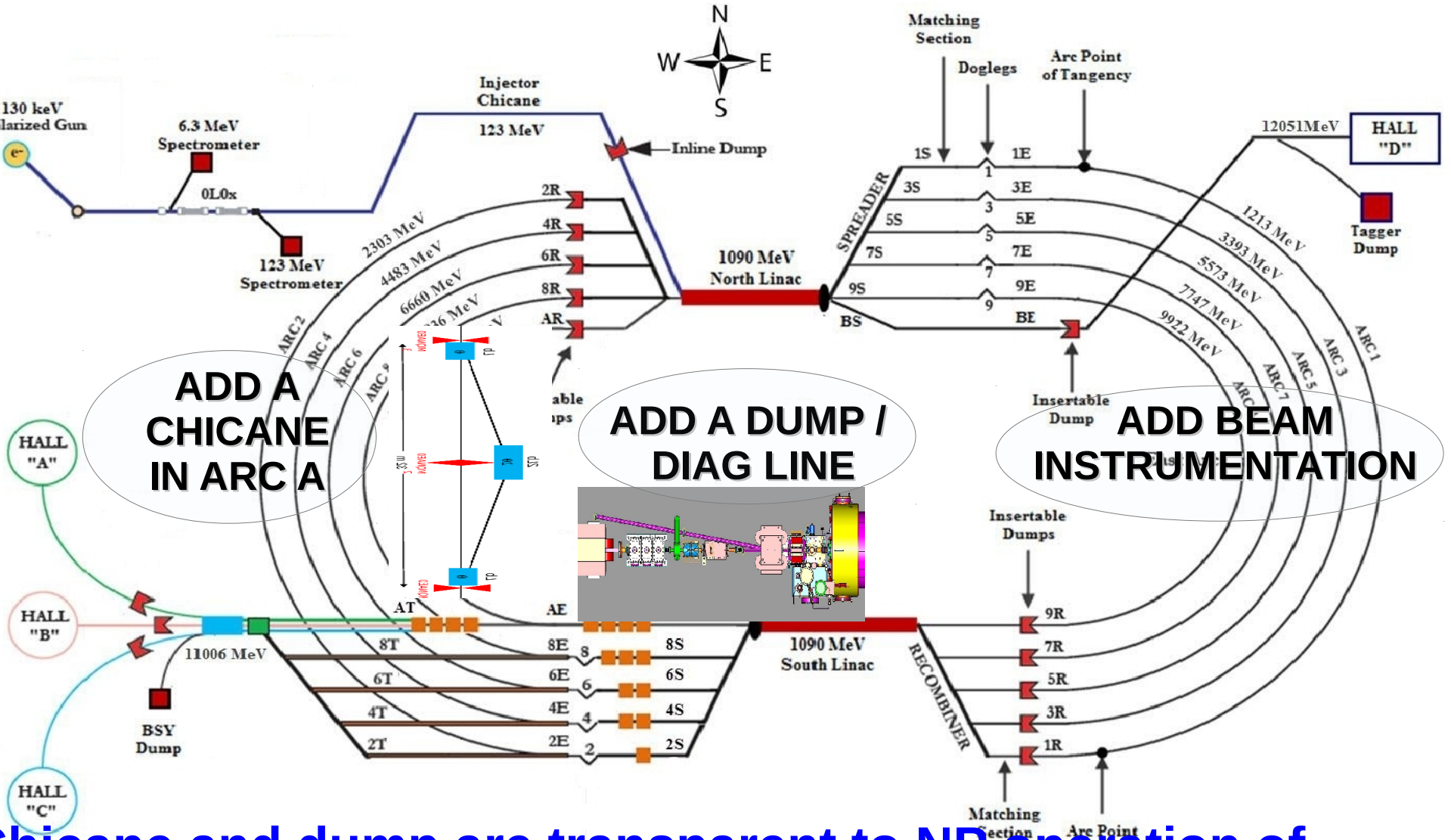
(iii) we maintain a dropbox collaborative space – active and well furnished !

▪ **Our goal at present : write a proposal for an ER@CEBAF experiment, to be submitted to JLab PAC44 (by June 6 2016).**

PAC44 is scheduled on 25 July

WHAT WE WANT TO DO : ER R&D, using CEBAF

High energy (7GeV, 700MeV/linac), multiple-pass (5)



- Chicane and dump are transparent to NP operation of CEBAF, could stay in place if allowed – for more eRHIC R&D

EXPERIMENTS THAT WE PLAN :

- **Staggered multiple-pass ER, up to 5-pass recirculation**
  - **- first, away from SR limitations, starting with 1pass up + 1 pass down**
  - **- ultimate expected to be 700~750 MV/linac (dp/p acceptance in arcs)**
  - **- characterization of bunch emittances at a series of locations – transverse possible at each pass in Hall B, dE and bunch length in A or C line, 6D tomography in dump line open topic, high dynamic WS, BPMs, etc**
  - **- RF system aspects, response to ER**
  - **- explore SR effects at higher energy (700 MeV/linac and beyond)**

- **Beyond ER R&D : take this opportunity for further ERL related R&D, including for instance**
  - **- Beam dynamics in presence of cavity HOMs**
  - **- Halo dynamics**
  - **- Multiple-beam diagnostic instrumentation**
  - **- spin dynamics in the presence SR, up to 12 GeV in Hall D**

SOMETHING THIS COMMMITTEE MIGHT CONSIDER CONTRIBUTING :

- **Manage to have BNL and JLab managements talk together prior to PAC44**

- **In view of gaining their expressly support to our project**

(avoid “conditional approval” ? 1 to 2 years delay)

BACKUP SLIDES

Excerpt, C-AD eRHIC meeting, 10 Feb. 2016

2/ What is our goal with JLab PAC44 (a personal viewpoint) ?

(i) Might "just" be : getting green light to construct (dump/diag line, chicane)

- we have no interest to undergo "conditional approval" which means a 1 or 2 years delay that goes with it.
- machine modifications can be done during shut-down periods
- how long it will it take etc. will be part of the infos in the proposal

(ii) In the proposal we can stress that

- modifications in CEBAF will be minor, transparent to normal operation
- and in addition, for a unique result : an ER experimental facility, transparent to CEBAF physics programs

(iii) In the mean time we can work at finding money for extended, dedicated CEBAF runtime for eRHIC R&D (as opposed/in addition to PAC44 package ?)

What we want to demonstrate in the matter of ER in relation with eRHIC (TBD!), how long we plan, how much runtime it means, etc, will be part of the infos in the proposal

ER@CEBAF
Parameter list

Machine/Lattice Parameters

Parameter	Value/Range	Units	Description
f_{RF}	1497.0	MHz	Standard CEBAF RF frequency
λ_{RF}	20	cm	Standard CEBAF RF wavelength
E_{linac}	700.0	MeV	Energy gain per linac pass(1)
E_{inj}	78.99	MeV	Energy of beam from injector (=E_{linac}*123/1090)
N_{passes}	1, 5	--	Number of machine passes before energy recovery(2)
$\varphi_{FODO, NL}$	60	degrees	Phase advance/cell, north linac(3)
$\varphi_{FODO, SL}$	60	degrees	Phase advance/cell, south linac(3)
M_{56} (Arc A)	80-90	cm	M_{56} compression of arc A(4)
M_{56} (other arcs)	0	cm	M_{56} compression of other arcs(4)
$\theta_{extraction}$	8	degrees	Extraction angle(5)
P_{dump}	20	kW	Maximum dump power (CEBAF standard)
$\Delta\varphi_{MOmod}$	0.25	deg	MOmod pathlength control tolerance(6)

1. Gradient distributions through the linacs remain to be optimized, and indeed may be different. E.g. Gradient distribution in the SL may be strongly weighted towards the end of the linac in C100s to defer beam deceleration as long as possible.
2. A 1-pass experiment is envisioned to reproduce/improve on 2002 results, check instrumentation, RF loops, etc.
3. From Alex Bogacz linac optics optimization.
4. From Yves Roblin longitudinal match optimization.
5. From Mike Spata extraction line design.
6. MOmod is a Master Oscillator modulation feedback that provides pathlength/phase control for the main RF. New MOmod electronics/pathlength control may even do 0.1 degree.

ER@CEBAF
Parameter list (cont'd)

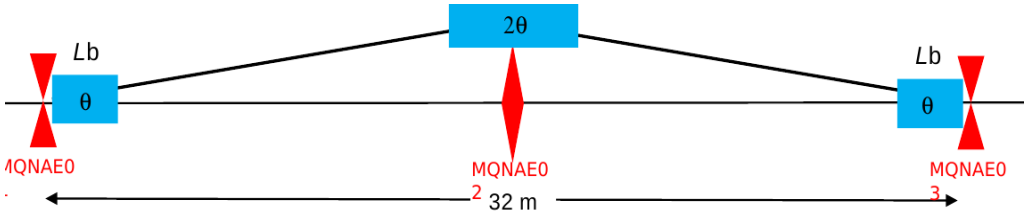
Beam Parameters

Parameter	Value/Range	Units	Description
$f_{beam,\ CW}$	249.5	MHz	Standard CEBAF CW bunch repetition frequency (31 MHz to 499 MHz in
			doubling/halving harmonics)
$f_{beam,\ tune}$	7.485	MHz	Standard CEBAF tune bunch repetition frequency (=0.015*f_{CW})
$I_{beam,\ max\ CW}$	100	µA	Maximum CW beam current
$q_{bunch,\ max\ CW}$	0.2	pC	Bunch charge (at 100 µA CW)
	1.5%	--	Tune mode fraction of CW[(7)]
$\sigma_{bunch,\ L}$	90-150	µm	Bunch length (high energy)
$\sigma_{bunch,\ t}$	300-500	fs	Bunch length (high energy)
$\varepsilon_{x,y,geom,inj}$	$\sim 10^{-8}$	m-rad	Transverse RMS geometric emittance at injector
dp/p_{inj}	$?.?x10^{-?}$	--	Momentum/energy spread at injector
$\varepsilon_{x,y,geom,extraction}$	$o(10^{-8})$	m-rad	Transverse RMS geometric emittance at 10-pass (5-up, 5-down) extraction
$dp/p_{extraction}$	$?.?x10^{-?}$	--	**Momentum/energy spread at extraction**

7. Tune mode beam: (250 µs macro-pulse filled, 100 µs off, 4 µs macro-pulse filled, then off) repeating at 60 Hz (every 16.67 ms). 4 µs trailing pulse used for linac BPM orbits and linac arrival time cavities (time multiplexed). See tuneMode.png.

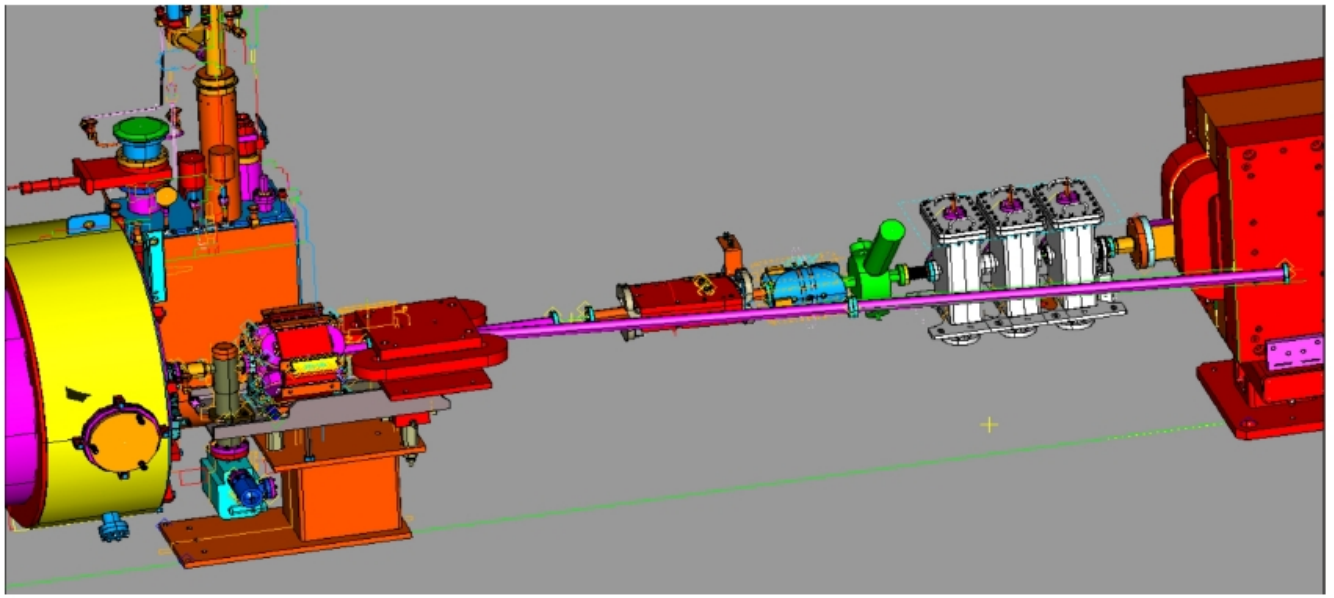
Experimental setup : phase chicane

A chicane is installed in ArcA, to create the lambda/2 (10 cm) delay necessary for 5-pass bunch deceleration upon re-entry into NL after 5 accelerated passes



Experimental setup : switch to dump line

A small chicane is installed at the exit of SL, which steers the ER'ed beam into the dump line.
Extraction angle 8 degrees.



The way an ER experiment could be started (M. Tiefenback)

- Start with reasonably low linac energy, thus
  - avoid SR effects, all the way to dump
  - Test diagnostics, protocols, etc.
- A possibility would be to use the C100 cryostats only, and thus
  - avoid coupling issues introduced by 5-cell cavities
- Evaluate multiple-beam orbit correction schemes in linacs
- Preliminary steps for ER setup could include
  - single linac acceleration (NL) / deceleration (SL), including preliminary tests at dump
  - Followed by 1-pass up, 1-pass down, test 2-beam diagnostics

An approach to the cost of ER@CEBAF cf. 2003's experiment

Proposal P-02-102
CEBAF Energy Recovery Experiment

Co-Spokesmen: Alex Bogacz, Andrew Hutton

Equipment Costs

All costs include procurements and labor

Mechanical cost	$172.3 k
Electrical cost	$67.2 k
Total cost	$239.5 k

Installation time ~ 4 weeks

Jefferson Lab — Thomas Jefferson National Accelerator Facility

- **The 2003 proposal to the Program Advisory Committee :**

- estimate at that time was ~250k$ to field the experiment. 15 years of escalation at 3% brings this to ~375k$

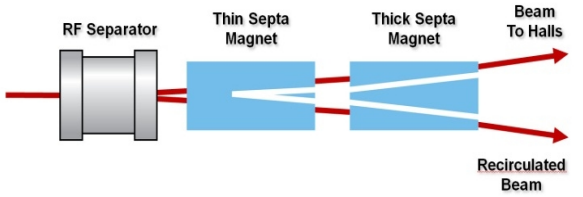
- for the 5-pass experiment, would need to scale appropriately the delay chicane for the higher energy (~330k$)

- dump and instrumentation are already available. Just need to be relocated.

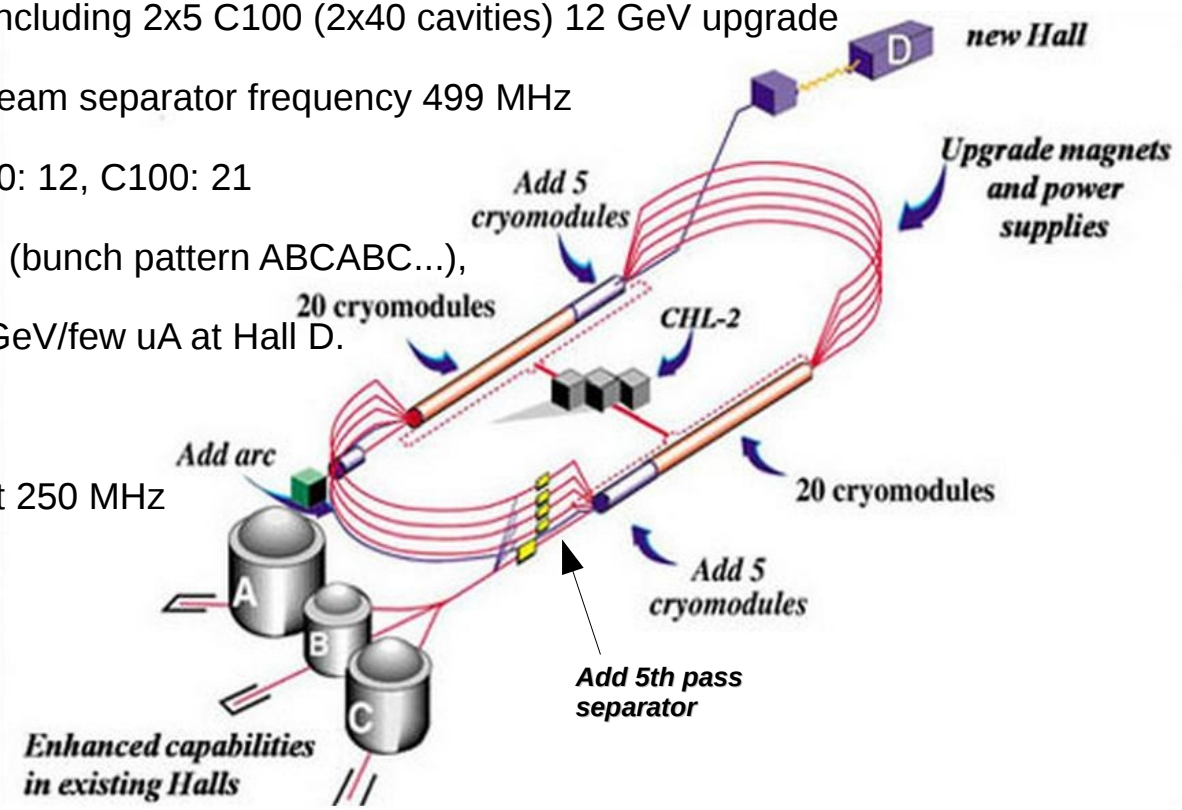
- add around 1 man-month for a cryomodule to be removed for the test and then reinstalled when test is over.

- **Labs interested in the field may want to collaborate and contribute**

CEBAF in figures



- Two 1.09GeV linacs, 52 SRF cryomodules, including 2x5 C100 (2x40 cavities) 12 GeV upgrade
- Operating frequency of linacs : 1497 MHz. Beam separator frequency 499 MHz
- Max gradient in cavities (MV/m) : C20: 9, C50: 12, C100: 21
- Interleaved 499MHz beam delivery to 3 halls (bunch pattern ABCABC...), with independent E, I, polarization. Only 12 GeV/few uA at Hall D.
- Transit time around the ring 4.2 us
- Max I at Halls A, C: 85 uA, 0.34 pC/bunch at 250 MHz



- Accelerator tuning is always done using low average power beam.
- The 250 μs pulse width at 60 Hz provides a 1.5% duty cycle.
- Nominal pulse height is 4 μA.
- Beam power is 720 W for a 12 GeV beam at this duty factor.
- The 4 μs trailing pulse is for measuring linac BPM orbits and linac arrival time.
- (FM) The 250 mus train fills the RF cavities